Production Technology of Fruit and Flower

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Production Technology of Chestnut

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Abstract

This book chapter delves into the multifaceted world of chestnuts, offering a comprehensive exploration of their cultivation, genetic diversity, and culinary applications. The chapter begins by tracing the historical significance of chestnuts across different cultures and regions, highlighting their role as a staple food source and their cultural importance. A detailed analysis of chestnut cultivation practices follows, encompassing soil requirements, climate considerations, and sustainable farming techniques. The genetic diversity of chestnut varieties is a focal point, examining the rich tapestry of different species and their unique traits. The chapter also discusses the challenges faced by chestnut trees, including diseases and pests, and explores innovative approaches to mitigate these risks through breeding and genetic research. Culinary enthusiasts and food scientists will find a wealth of information on the culinary uses of chestnuts,

from traditional recipes to contemporary culinary innovations. The nutritional value of chestnuts and their potential role in addressing global food security challenges are also explored. Throughout the chapter, a balance between traditional wisdom and modern scientific insights is maintained, offering readers a holistic view of chestnuts that spans cultural, agricultural, and gastronomic dimensions. This chapter serves as a valuable resource for researchers, farmers, and food enthusiasts eager to deepen their understanding of this versatile and beloved tree species.

Keywords: Chestnut, fagaceae, gall wasp, nut rot and self-sterile.

Common name: Chestnut

Botanical name: European - *Castania sativa,* Chinese - *Castanea mollissima,* American - *Castanea dentata* and Japanese - *Castania creneta*

Family: Fagaceae

Origin: China

Chromosome number: 2n = 2x = 24

Other names: Sardian nut, Jupiter's nut, husked nut and Spanish nut

Type of fruit: Nut

Type of pollination: Anemophilous and entomophilous (Wind and insect pollination).

Introduction

The chestnut is similar to the acron of oak. The chestnut trees are growing in temperate climate of the world for more than 4000 years for beauty, fuel and shelter. The sweet chestnut is a nutritious low in fat and rich in Vitamin B. Freshly harvested nuts contains about 50 per cent moisture, 40-42 per cent carbohydrates, 2.9 per cent proteins and about 1.5 per cent fats. In addition to good food source to human being, chestnut also provides food for number of wild life species. Its wood is durable and used for timber and furniture work. Chestnut and chinquapins are exception to all other nut trees in that they contain little oil and are high in carbohydrate particularly in starch.

Origin and distribution

The Fagaceae family is often divided into 5 or 6 subfamilies that are generally accepted to include 8-10 genera. According to the Angiosperm Phylogeny Group III (APG III) classification, this family includes 7 genera (Castanea, Castanopsis, Fagus, Lithocarpus, Quercus, Trigonobalanis, and Chrysolepis) and almost 700 species. The genus Nothofagus is included in the list, according to Royal Botanic Gardens of Kew, or attributed to a specific family Nothofagaceae, according to the APG III classification.

Botany and taxonomy

The genus Castanea is widespread in the Boreal Hemisphere and includes as many as 13 species according to the classification given by Bounous and Marinoni in 2005. The natural distribution of the European chestnut (*Castanea sativa* [C. sativa]) includes the European and Mediterranean countries and is mostly used for the nut and timber. In Asia (China, Korea, Japan, and Vietnam), *Castanea crenata* (Japanese chestnut), and *Castanea mollissima*, *Castanea seguinii*, *Castanea davidii* and *Castanea henryi* (Chinese chestnuts) (Willow leaf or pearl chestnut) occur. *C. henryi* is cultivated in Zhengjiang, Fujian, and Hunan Provinces in South China as a fresh nut, whereas *C. crenata* and *C. mollissima* are cultivated for nuts, and *C. seguinii* and *C. davidii* are cultivated for firewood. In North America, the native range of *Castanea dentata* is from Maine to Florida, while *Castanea pumila ashei* or *C. ashei* is found in southeastern states. *Castanea floridana* (Florida chinkapin), *C. ashei* (Ashe chinkapin), *Castanea alnifolia* (Creeping chinkapin), and *C. paucispina* are the native plants of South USA. The most important species, cultivated for nut production, are *C. mollissima* (Chinese chestnut), *C. sativa* (European chestnut, Spanish chestnut, Sweet chestnut), *C. crenata* (Japanese chestnut), producer of large size nuts, and their hybrids. The European chestnut is also a source of timber and other forest products, and it is prized as an ornamental in the landscape.

Composition and uses

Chestnut fruits were considered very important food sources in European and Asian rural areas for many centuries. Nuts were used in different ways: roasted or boiled in water or milk and consumed instead of bread or served hot with wine or milk as a soup. However, a progressive decline in their production in the 1990s was caused by the emergence of severe tree diseases and the rural depopulation. More recently, there has been a resurgence in demand for traditional foods as value-added products. Consumers also have a renewed interest in chestnuts due to their nutritional quality and potential health benefits.

Chestnuts are good sources of starch (up to 70%), minerals (especially potassium and, to a lesser degree, calcium, sodium, and phosphorus), lipophilic vitamins (vitamin E), and appreciable levels of fiber (7%–8%), but contain low amounts of protein (2%–4%) and, unlike other nuts, fat (2%–5%). They also contain antioxidant compounds, such as polyphenols and hydrosoluble vitamins (in particular, C, B1, and B2). Additionally, chestnuts are a source of essential fatty acids, mainly linoleic acid; these compounds present an important activity against cardiovascular diseases in adults and promote the development of the brain and retina of infants.

Area and production

There is no organized plantation of chestnut in India, only stray plantation exists and some plants grows wild in the forest of Himachal Pradesh, Darjeeling and Khasi hills. Leading countries in the chestnut production are USA 526000 MT, China 101000 MT, Turkey 99000 MT; Korea 70000 MT Italy 53000 MT; Japan 48000 MT and Spain 31000 MT; Total world production of chestnut is nearly 477,568 metric tons in an area of 18430 ha plantation with average productivity of about 1.84 T/ha (FAO, 2022).

Flower and fruits

The Chinese chestnut is latest tree to bloom. The flowers are produced in two kinds of catkins borne on current season shoots near the terminal portion of the shoot. The fruit of the Chinese chestnut is borne in a spiny involucre known as bur. Three nuts are usually produced in each bur (upper, left and right). The bur is a vegetative structure that encloses the nuts or fruits. Botanically, each nut is a complete fruit The shell of the nut develops from the ovary wall. The kernel of the nut is a young embryo plant that develops from the fertilized eggs of ovule. The edible portion of the kernel is made up of two fleshy cotyledons and minute internal growing points of shoots and root. The kernel is enclosed in a membranous covering called the pellicle, which originate from the integument of the ovule.

Soil and climate

Soil

Chestnut can be grown in all types of soil but it grows best in well drained sandy or sandy loam soil. The soil should be moderate to slightly acidic. The chestnut trees withstand moderate drought after well establishment.

Climate

The chestnut can be grown in a wide range of climate in temperate areas. It is as hardy as peach and can withstand as low as -29oC temperature in deep dormancy. It requires less chilling to break bud dormancy in spring. Buds respond quickly to warm temperature and thus become subject to damage by late spring frosts.

Soil and climate

Site selection is an important factor in the establishment of new high-density and traditional plantations. Generally, low and mid-mountain hilly areas are preferred for many Castanea species because they are well sun-exposed and protected by spring frosts. The best soils are acidic (pH 5–6.5), light textured, fertile, and well drained. Heavy clay, high pH, and poorly drained soils negatively affect tree growth and also contribute to the spread of Phytophthora-borne diseases. A sufficient water supply for the European cultivars is ensured by a rainfall of over 800–900 mm/ year, while C. mollissima, C. henryi, and Euro-Japanese hybrids need 1200–1300 mm/year.

Varieties

Most of nurserymen in Western countries grow only seedling plants because of their easy availability at lower price, however, grafted trees are superior to seedling in nut production. The cultivars which are of commercial importance are: Abundance, Crane, Kuling, Meiling, Nanking, Orrin, Colby and Hemming. Today chestnut diversity is the result of the co-evolution between the Castanea trees and the human cultivation of its species. Over the centuries, large quantities of heterogeneous chestnuts have been produced for fresh consumption or to be preserved as a staple during winter in rural areas. Currently, superior cultivars are selected for plantations to supply high-quality nuts required by consumers (e.g., regular in shape, good flavor and texture, sweet, easy to peel, without pellicle intrusion or hollow kernels, and no shell splitting). Nut descriptors can be used to understand the traditional uses of a variety, but phenomorphological observations are ineffective for genotype identification, because the nut is strongly influenced by environmental factors and cultural practices. Therefore, the cultivars are usually characterized phenotypically and genotypically using micro- satellite markers (random-amplified polymorphic DNA, simple sequence repeat, inter-simple sequence repeat, amplified fragment length polymorphism, Sequence-related amplified polymorphism). Many excellent *C. sativa* cultivars are grown in France, Greece, Italy, Portugal, and Spain that present hundreds of named cultivars selected for different uses (e.g., candying, roasting, drying, flour, or fresh consumption). In Italy, highly prized cultivars are the Marrone type ("Chiusa Pesio," "Val Susa," "Castel del Rio," and "Marradi"). Marrones are characterized by their large size and are sold for fresh market and candying (marrons glaces). Interspecific hybrids (*C. sativa* × *C. crenata*), resistant to ink diseases and suitable for fresh consumption, such as "Bouche de Betizac," "Maridonne," "Marigoule," and "Precoce Migoule," have been selected by French researchers.

In Portugal, "Longal," one of the most ancient cultivars, found growing throughout the chestnut regions (Tras-os-Montes, North Eastern Portugal), is considered the best cultivar for the agri-food industry. "Judía" and "Martaínha," due to their larger nut size, are usually promoted for fresh consumption. Important cultivars in Spain are "Parede," "Longal," "Amarelante," "Negral," "Injerta," and "Verata" propagated profusely during the last 300 years. In Japan, most commercial cultivars are Japanese chestnuts (*C. crenata*). Only few cultivars like "Riheiguri" are Japanese × Chinese hybrids. More recent plantings of grafted trees (C. crenata on C. crenata rootstock) are precocious (bearing 4th–5th year after planting). C. crenata trees also produce large size nuts with a marked hilum and are sweeter than the European ones. "Ishizuki," "Tsukuba," "Tanzawa," and "Ginyose" cultivars are also resistant to canker blight and ink disease.

Reciprocal crosses of *C. sativa* × *C. crenata* have been obtained in France by Institut national de la recherche agronomique (National Institute of Agricultural Research) to evaluate ink disease and canker blight resistance. Some Euro-Japanese hybrids are used on their own roots or as a rootstock. Trees of these hybrids have early ripening nuts and are more vigorous than C. crenata trees. Their nuts are suitable for fresh consumption and industrial processing, and they usually mature earlier than European ones. Euro-Japanese hybrids prefer low altitudes, deep soils, and frost-free sites.

High-density orchards of *C. mollissima* have a relatively small tree size and bear a large crop of nuts at a young age. This species is the most blight resistant, although it may be affected by Cryphonectria. Fruits are usually easy to peel with a nut weight between 10 and 30 g. More than 300 C. mollissima cultivars or ecotypes are described in China with subtropical types usually with larger nuts than northern ones. Large nuts are processed and exported to southeastern Asia. Superior cultivars include "Qingzha," "Duanzha," "Jiaoza," "Jiujiazhong," "Jiandingyouli," "Tanqiaobanli," "Qiancidabanli," "Yanshanzaofeng," "Zhenandabanli," and "Daiyuezaofeng" grafted onto C. mollissima seedlings. These cultivars were selected for commercial use in China.

Propagation

Chestnut seeds planted immediately after harvest showed poor germinate. The seeds are stratified for 50-60 days in moist sand at 0 to 2.2 °C to break dormancy of chestnut embryos and ensure uniform germination. The chestnut stratification in moist sand kept in wooden boxes at cool shady place proved better than in refrigerator because of fluctuating temperature under field condition help in promoting the seed germination. The stratified seeds are sown in nursery beds in the month of March.

Chestnut trees are clonally propagated by grafting, cutting, and tissue culture to guarantee trueness to the type of superior cultivars. Tree uniformity in high-density plantations is essential for establishing trees at close spacings and managing the nut crop. When grafting trees, the use of clean scion wood is essential for the propagation of pest-free trees. Scion wood collected from plantings that may be infested with Asian chestnut gall wasp (*Dryocosmus kuriphilus*) can be immersed in hot water (52 °C) for 10 minutes to kill overwintering larvae present in chestnut buds. However, the collection of scion wood from areas free of D. kuriphilus ensures the propagation of non-infested trees.

Rootstocks: Rootstocks influence tree growth and longevity, disease resistance, stress tolerance, and nut size. Seedling rootstocks of a compatible chestnut cultivar are often used to produce grafted trees. Seed size, origin, viability, and germinability are important factors in the production of seedling rootstocks. Rootstocks show important effects on the scion performance and, consequently, they also influence the tree growth and nut size. Seeds are not able to immediately germinate at harvest, and a postharvest treatment (e.g., stratification) is required in order to overcome dormancy. In nature, seeds are often covered by leaf litter in the fall and are naturally stratified. In Europe, propagators place nuts in a sand, peatmoss, or sawdust layer (5–8 cm), in a stratification box in an outdoor sheltered site or in a cold room for three months before germination to avoid extreme temperature fluctuations and fungal decay.

Some species of chestnut are used as rootstock for propagation. Chestnut are highly cross pollinated and hybrid seedling used as rootstock is a possible cause of graft union failure in chestnut. Therefore, mixed hybrid strains should not be used as rootstock. In early spring, the germinants are then sown at 30 cm apart in outdoor raised beds (25–30 cm in depth) to avoid ink disease (*Phytophthora* spp.). Outdoor beds may also be covered by a black plastic film, leaving a 40 cm access space between the beds. For seedling rootstock production in the USA, nuts are stratified at 5 °C in a cold room and then planted in containers for air-root pruning in greenhouses before grafting.

Grafting and Budding: The chestnut has only one bud at each node and if it is killed by spring frost bud break fails. So early grafting should be avoided. Splice grafting and tongue grafting done in March are generally used for the propagation of chestnut. Chip budding also perform well. Grafting and budding are mainly used to propagate clones and cultivars performing different techniques as chip budding, whip and tongue, cleft, and bark grafts. Dormant scion wood is collected from mother plants pruned during the previous year. Another propagation method, stooling, is used to multiply some Euro-Japanese hybrids: it produces rootstocks rooted on trees of the parent variety. Chestnut was previously considered difficult to propagate by cuttings, but this method is currently used to produce hybrid trees in France, Italy, Spain, and Portugal. Tree propagation by tissue culture is still difficult.

Layout and planting

New orchards tend to utilize compact trees grafted onto rootstocks that bear large-size nuts in the fourth year after planting. The planting distance depends on the cultivar vigor and rootstock. The growth habit of trees is also variable depending on species and cultivars. *C. sativa* trees are generally upright and tall, while those of *C. mollissima* are relatively smaller.

Planting density: The planting is done during winters. Before planting, the site should be properly laid out with contour or terrace systems. The pit should be prepared well in advance and refilled with soil mixed with 60 kg well rotten FYM. Plants should be spaced about 30 feet apart as trees are very large in canopy.

Various pruning techniques are used to maximize light interception for the production of high-quality nuts. Tree spacings for European chestnut cultivars vary from 8 m × 12 m to 12 m × 12 m, while those of less vigorous Euro-Japanese hybrids range from 7 m × 7 m to 10 m × 10 m. Japanese and Chinese cultivars may be planted closer, depending on local site conditions.

Post-planting weed control is important during the establishment phase (first 3–4 years). Organic mulches, such as pine bark, saw dust, grass, straw, and wood chips, can not only conserve moisture for trees and provide the organic matter, but can also increase vole or rodent damage to tree trunks during winter. A weed-free zone (1–2 m under the trees) can also be maintained, using registered herbicides or tilling as an alternative to mulch.

Pollination

All cultivars and species of chestnut are self-sterile. Two or more cultivars and seedling must be planted in the orchard to ensure cross pollination. Young orchard trees may not set nuts when the first flowers are formed because of lack of pollination. When young trees start flowering the few staminate catkins apparently do not produce enough pollen to fertilize the pistillate flowers. Chestnut is wind pollinated as well as insect pollinated.

Canopy management

Pruning

The Chinese chestnut form a low headed tree if left unpruned. Unpruned tree starts bearing earlier than severely pruned ones. Early pruning stimulates vegetative growth. Hence, for early nut production orchard trees should not be pruned for few years. An ideal practice is to allow the trees to come into bearing before any pruning is done, then remove only a few of the lowest branches each year until the tree is properly headed. Lower limbs are removed gradually from the tree and the practice is continued. The lowest branch should be kept at a height of one meter from the ground and therefore branches should be spaced spirally at a distance of 40 cm from one another.

Training

Pruning is necessary to increase the light interception in the canopy, resulting in a regular nut crop (without biennial bearing), increased productivity, and larger nut size. The traditional open vase pruning system is particularly suitable for European chestnut trees. For this system, the 3–4 branches, equidistantly spaced around the trunk with wide branch angles, are selected. At the end of the fourth year, trees are usually well shaped, and subsequent pruning is limited to thinning out crowded branches, and eliminating dead, broken, or damaged wood. For high-density plantations (more than 150–200 tree/ha), a pyramidal training system is used in which the central leader is dominant.

Nutrient management

The chestnut trees are mostly planted on eroded upland soils, so it is important to fertilize trees regularly. At least ½ kg 15:15:15 NPK mixture per year age of tree should be applied before sprouting or in early spring. The full bearing trees should be supplied with 100 kg FYM and 6-8 kg of NPK mixture during December – January.

Manure and mineral fertilizers are often incorporated into the soil. In Italy 40–50 ton/ha of cow manure is soil incorporated at a depth of 20–30 cm, resulting in an organic matter content of at least 2%. Mineral fertilizers with phosphorus (10–20 ppm) and potassium (100–150 ppm) are applied as mineral superphosphate and potassium sulfate, respectively. Nitrogen, easily leached away, is applied during the spring (250 g/tree of ammonium sulfate or ammonium nitrate) to stimulate vegetative growth.

During the adult phase, the most limiting nutrient is nitrogen, which is applied in early spring and in late spring. The nitrogen inputs depend on the plant age. An application protocol for the first five years of a C. sativa orchard. In the USA, fertilizer application rates for bearing orchards are determined by foliar analysis. On fertile soils, a significant increase in the nut yield occurred when ammonium nitrate was applied at 70 kg/ ha on April 1 and June 15, resulting in a foliar nitrogen content of 2.4%. From the sixth year onward, a broadcast application of 60–80 kg/ ha/year of nitrogen can be applied (0.3–0.4 ton/ha of ammonium nitrate), depending on productivity. Phosphorus and potassium can be applied at longer time intervals, based on the plant needs. Potassium deficiencies are common in light texture soils and, if detected, K applications are suggested in a range from 25 kg/ha (6-year-old plants) to 120 kg/ha (over 10-year-old trees).

Irrigation

Well established trees can withstand a moderate amount of drought. Chestnut is generally grown under rain-fed conditions but needs adequate moisture for at least 2 months after blooming. Irrigation at fortnightly intervals after blooming is desirable for better fruit size, yield and nut quality. The need for irrigation depends on local pedoclimatic conditions, particularly the annual rainfall. Young chestnut trees are drought intolerant and are difficult to grow without irrigation. The highest tree demand for moisture is from late spring through harvest. Tensiometers are useful to determine when irrigation is necessary. Drip irrigation systems are recommended to optimize water availability.

Flowering and fruit set

Chestnut is a monoecious species (pistillate and staminate flowers on the same plant), producing flowers on current season's growth. There are two kinds of inflorescences: the male catkins, located in the middle part of the shoot; and bisexual catkins, located at the middle and terminal portion of the shoot. Female flowers develop singly or grouped in clusters (two or three) on the bisexual catkins. Most of chestnut cultivars are self-sterile and require cross-pollination from another cultivar with a similar period of bloom. Abundant pollen quantities are produced by genotypes with long stamens, whereas others, including Marrone, produce sterile male flowers. Generally, chestnut is wind pollinated, but insects may help plant pollination.

Interculture

Row crops such as corn, soyabean or other pulses can be grown between the trees for the first few years. Filler trees of stone fruits can be planted for supplementing income in the early years and should be removed later on after chestnut plants start bearing full crops.

Pests and diseases

Insect pests

Carpophagous tortricid moths: They may represent a serious threat in several chestnut-growing areas in Europe. In particular, three species are considered as major pests of chestnut fruit: Pammene fasciana L., *Cydia fagiglandana* (Zeller), and *C. splendana* (Hübner) (Lepidoptera: Tortricidae). These moths are commonly known as the early chestnut moth, intermediate chestnut moth, and late chestnut moth, respectively. In Southern Europe, major damage is detected on sweet chestnut (*C. sativa*), but other common hosts are oaks (*Quercus* spp.) and beech (Fagus sylvatica) L. The flight period may occur from June to July for P. fasciana adults, and later in the season for C. fagiglandana (July–September) and C. splendana (August–September). All three species are oligophagous and univoltine, with larval instars developing in the fruit. Larvae penetrate and dig tunnels inside the nut cause an earlier fruit drop to the ground and significant yield loss. The etiology of these insects is quite similar. Mature larvae overwinter mainly in the soil or under the bark, while the emergence of the adults generally is recorded in the following late spring or summer, with diapause reported for some species. Chemical control is difficult because of the larval endophytic development; for this reason, low impact and biological strategies have been investigated. The seasonal flight period and population density have been monitored by pheromone-baited traps. In particular, the potential of sexual pheromones in specific control programs, as mating disruption or sexual confusion, and plant volatiles for practical application have been studied.

Chestnut weevil: Another important key pest in Europe is the chestnut weevil, *Curculio elephas* Gyllenhal (Coleoptera: Curculionidae). This univoltine insect develops both on chestnuts and acorns (*Quercus* spp.). Females lay their eggs by piercing the husk with their rostrum and inserting an egg into the hole. The newly emerged larvae penetrate the fruit and feed on the kernel tissues. Later, they exit the fruit to burrow into the ground to overwinter. Adults mate and lay eggs just after emergence from the ground in late August and September. The damage may be considerable, depending on the environment and the climatic conditions, with infestation rates up to 90%. As already pointed out for the chestnut moths, control of the larval stage is difficult because larvae occur within the chestnut fruit. The overwintering population could be reduced by killing the individuals occurring in the soil in order to prevent or reduce damage. Proper timing in applying control measures is critical for the containment of both tortrix moths and the weevil when they are not inside the fruit. Entomopathogenic fungi (e.g., *Metarhizium anisopliae* (Metch.) Sorok and *Beauveria bassiana* (Bals.) Vuill.) and nematodes (families Steinernematidae and Heterorhabditidae) have been tested in laboratory trials, especially against C. splendana and C. elephas last instar larvae, but results in field applications were often unsatisfactory. In North America, the lesser chestnut weevil (Curculio sayi Gyllenhal) and the larger chestnut weevil (Curculio caryatrypes Boheman) are major pests infesting chestnuts, resulting in significant crop loss in mature plantations.

Asian chestnut gall wasp: *Dryocosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipidae), in the last decade significantly impacted chestnut production, representing one of the most recent examples of exotic pest accidentally introduced in the European forestry environment. This gall wasp, native to China, established as a pest in Japan since 2002 in many European countries, affecting chestnut orchards and coppices (*Castanea* spp.). It is a univoltine and thelytokous species, and females lay eggs in buds during summer. In the following early spring, greenish-red galls develop on new shoots, suppressing elongation and causing twig dieback. Severe reduction of fruiting and yield losses have been estimated to reach up to 85% in Northern Italy. The community of native parasitoids recorded on *D. kuriphilus* is mainly composed of chalcid species (Hymenoptera: Chalcidoidea), commonly known to be parasitoids of oak cynipid gall wasps. Since many of these wasps are generalist, and their emergence time does not often coincide with gall development, they proved ineffective biocontrol agents for the control of the gall wasp. However, the exotic parasitoid, *Torymus sinensis* Kamijo (Hymenoptera: Torymidae), native to China, was released into Japan (1975), the USA (in the late 1970s), Italy (2005), and more recently in several other European countries (Croatia, France, Hungary, Portugal, Slovenia, Spain, and Turkey). It is univoltine, predominantly reproducing amphigonically (a specialized form of sexual reproduction) and it may exhibit a prolonged diapause mainly as late instar larva. After emergence in early spring and mating, *T. sinensis* females lay eggs inside the larval chamber of newly formed galls, usually one egg per host larva. After hatching, the larva feeds ectoparasitically on a *D. kuriphilus* larva and the parasitoid pupates in the host larval chamber during winter.

Diseases

Chestnut is affected by several diseases caused either by fungi or by fungal-like organisms, some of which, historically, have had tremendous effects on the cultivation of Castanea species. Few diseases may cause tree decline or mortality, while others are associated with the spoilage of nuts. The former group includes several foliar diseases and more importantly, the ink disease and the chestnut blight. Since the mid-1800s, serious epidemics of ink disease have been reported on both *C. dentata* and *C. sativa*.

Root rot: This is caused by *P. cambivora* and *P. cinnamomi*. Generally, these pathogens cause an initial underground infection of fine roots that may spread to the lower trunk area. Symptoms such as reduced shoot growth and premature leaf fall may occur, sometimes preceding tree death. Often, a dark and viscous substance bleeds from the bark at the base of the trunk in association with aboveground colonization by the pathogen. Also, necrosis of the cambial layer and phloem is apparent when bark is removed from the lower trunk and main roots are examined. The spread of the disease is mainly due to the movement of soil harboring pathogen inoculum, including sexual resting spores (i.e., oospores), and to the dissemination of asexual flagellated spores (i.e., zoospores) that can travel actively short distances or passively long distances in flowing water. Thus, infections are associated with sites characterized by accumulation of water like flood areas, poorly drained draws, underground water tables, and near unpaved roads or dirt tracks. Ink disease is hard to control because pathogens can survive as resting oospores for several years in infected host tissues or in the soil. Before planting, dead and diseased trees that harbor the fungus are removed, including their stumps and root systems. Mulching combined with organic amendments are also effective in controlling the disease, as well as chemical treatments. The control of ink disease can be also achieved by using resistant rootstocks. C. crenata and the hybrids C. sativa × C. crenata showed high levels of resistance.

Chestnut blight: It is caused by *Cryphonectria parasitica*, a fungus native to eastern Asia and introduced in the early 1900s in North America and then into Europe. The disease devastated the native *C. dentata* forests in the USA, as well as *C. sativa* trees in Europe. *C. parasitica* infects the trunk and branches of chestnut. On young trees, infections generally occur in the area of the graft. In coppices, old orchard trees and high forests, infections can be observed at the base of the trunk, along the trunk, or on branches in the crown. Chestnut blight in its typical virulent form leads to extensive necrosis and bark cankers. Cankers may rapidly enlarge and girdle the stem/branch, causing the death of plant tissue distal to the infection. Orange or reddish pustules (stromata) harboring the sexual (perithecia) and asexual (pycnidia) fruiting bodies of the fungus may develop on the infected bark. Infections occur by means of sexual or asexual spores through wounds or dead host tissues. In many European stands, chestnut trees gradually recovered from the disease. This recovery occurred thanks to a phenomenon called hypovirulence. Hypovirulence is caused by a virus (hypovirus, CHV-1), which affects both sporulation abililty and virulence of the fungus. The hypovirus can spread from infected to non-infected *C. parasitica* individuals via hyphal anastomosis between fungal strains belonging to the same vegetative compatibility (VC) type and via asexual spores (conidia).

Nut rot: Nut rots of chestnut are associated with pre or postharvest infection by a number of fungi, including *Ciboria batschiana*, causing a black rot, and *Phomopsis* spp., associated with a mummification of nuts. Although nuts rots may be locally and occasionally detrimental for nut growers, they have never threatened the cultivation of chestnut. However, since the mid-2000s, an increased incidence of nut rots has been reported in Europe and Australasia which was associated with a previously unknown disease caused by the newly described fungus, *Gnomoniopsis castaneae*. Depending on the location and year, substantial yield losses due to *G. castaneae* can occur. For instance, disease incidence as high as 93% was reported in northwestern Italy. Infected nuts show a brown discoloration and a peculiar texture degradation with the kernel appearing sometimes chalky and dehydrated. Interestingly, the fungus is also present with high frequency and asymptomatically in buds, bark and green tissues. This fungus has also been reported in association with cankers similar to those caused by *C. parasitica*. Sexual spores released from perithecia on burs are responsible for floral infection. Infectious conidia can be released from acervuli that develop on galls of the Asian gall wasp *Dryocosmus kuriphilus*. However, infection by means of sexual spores is prevalent in the biology of *G. castaneae*. Hence, an effective control strategy could rely on the removal of fallen burs.

Maturity and harvesting

The chestnut matures in the first fortnight of October in Himachal conditions. The bur colour changes from green to light brownish and split open during maturity releasing the nuts. Chestnuts are very perishable crop that require prompt harvesting every third days. Traditionally, chestnuts are hand gathered from ground after falling naturally. In USA and other developed countries, the chestnuts are harvested mechanically by shaking the burs from the trees and using mechanical pick-up device together the nuts.

Harvesting

Chestnuts are traditionally manually harvested, resulting in a high labor cost. Before harvesting litter removal underneath the trees accelerates chestnut collection and nets may also be used. Low-cost harvest equipment, using a paddock vacuum system, has been developed in the USA for small-scale orchards. More expensive harvesting machines are commonly used in high-density orchards, such as suction or sweeper harvesters. Daily harvesting is preferred to reduce the incidence of disease infection.

The harvested chestnuts are treated with fungicides to prevent spoilage. These nuts are then cured for 5 days at 21°C. on an average, the harvest period of each tree is 23 days as maturity is not uniform in chestnuts.

Yield

Seedling tree yielded 26 kg of nuts at 12 years of age.

Storage

Fresh chestnut contains 40-45 per cent carbohydrates, mostly in the form of starch, about 5 per cent oil and about 5 per cent moisture. These are highly perishable because the nuts loose moisture rapidly at room temperature, causing the kernel to become hard and inedible. For storage, the moisture of nuts must be less than 10 per cent and relative humidity of storage atmosphere must be 70 per cent or lower and storage temperature must be 0 °C or lower. Mold on chestnut can be destroyed with hot bath (57.7 °C for one hour). The best way of drying chestnut is to put them in bags at 4.4 °C with well circulated air at 70 per cent relative humidity. Under these conditions the nuts will cure and dry to the optimum moisture content.

Post-harvest handling and storage

Chestnuts are highly perishable and are placed in cold storage immediately after the harvest. Traditional and modern methods are used to maintain nut quality, reduce metabolic activity, delay mold growth, and limit worm-infested nuts. For curing, nuts are submerged in water (18 °C–20 °C) for 4–7 days and then thoroughly dried. Cured nuts can be stored for 5–6 months without loss of quality. For sterilization, chestnuts are put in water at hot temperature (50 °C) for 45 min, then air dried on sanitized cement floors or by fans for several days, and finally stored for 3–4 months.

For dried chestnut-based products, the nut moisture content is decreased to 10% of the original fresh weight. In some areas (e.g., in Italy and France), specific cultivars are produced for this use. Dried nuts are peeled and selected before marketing; after selection, they can also be grinded into flour. For the controlled atmosphere storage, nuts are placed in rooms maintained at 20% CO2, 2% O2, 1 °C–2 °C, and 95% relative humidity. This storage method reduces fungal infection and results in a high-quality final product. Whole or peeled chestnuts can be frozen at −40 °C for 12 hours and then stored at −20 °C and 80%–90% relative humidity for more than one year. Generally, this technique is used for the highest quality and valuable chestnuts, such as Marrone types.

Processing and value addition

Most of the chestnuts produced are sold to the fresh market, with a high demand at the beginning of the harvest season in the Northern Hemisphere. The "Fresh Fruit and Vegetables (FFV) Standards" of the United Nations Economic Commission for Europe are used by governments, producers, traders, importers, exporters, and other international organizations to define nut quality and sizing, related tolerances and traits, and to regulate marketing. The FFV Standards apply to chestnuts (C. sativa, C. crenata, and their hybrids) for fresh consumption, whereas sweet chestnuts for industrial processing are excluded from these regulations. While chestnuts are graded into different commercial sizes, "Marrone" types are often distinguished from other chestnuts in European countries. Italian quality standards designate Marrone as a cultivar or a group of cultivars with specific morphological and sensory traits as an oblong shape, large size, small hilum, light color and lightly raised stripes, easily peeled, rarely double kernel, good flavor, and consistent texture. A simpler definition is used by France. French quality standards classify any chestnut with less than 12% of double embryo as Marrone.

Semi-processed chestnuts are peeled or peeled and frozen or processed in purée, becoming a basic ingredient for many products. Whole peeled chestnuts may be water packed in tins, dry packed in glass jars, or boiled and vacuum packed. The best chestnuts and Marrone types (peeled and frozen) are candied for marrons glaces or are used in syrup and in alcohol. Chestnut purée is often used for creams in desserts. Dried and roasted chestnuts, and flour are packed and sold throughout the year.

Fig 1. Chestnut harvesting by (A) hand and (B) mechanical way

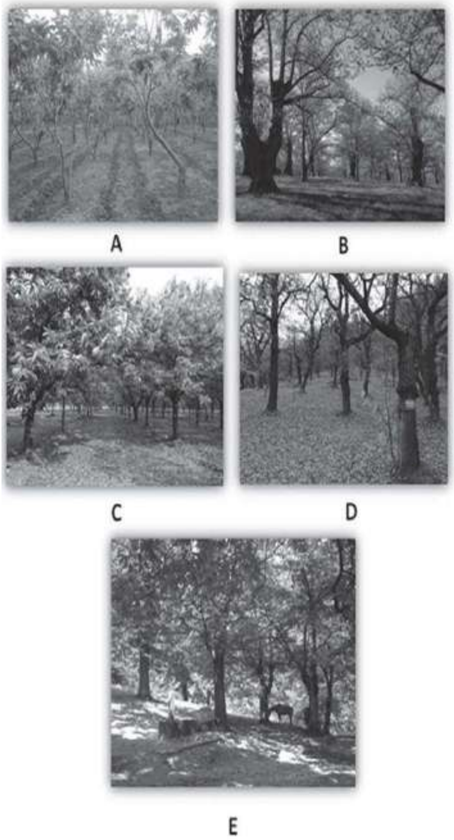
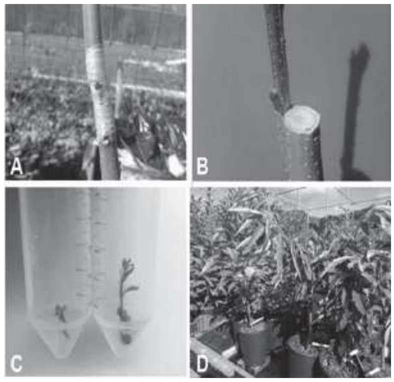


Fig 2. ***C. mollissima*** **plantation in Northern China (A), European traditional plantation (B), high-density plantation of** ***C. sativa*** **hybrids (C), traditional plantation in Northern Italy (D) and traditional plantation in Switzerland (E)**



(A) C. sativa bud grafting, (B) chestnut crown grafting, (C) micropropagation of C. sativa hybrid, and (D) plants growing in pots at nursery.

Fig 3. Roasted chestnut in Bangkok, Thailand market

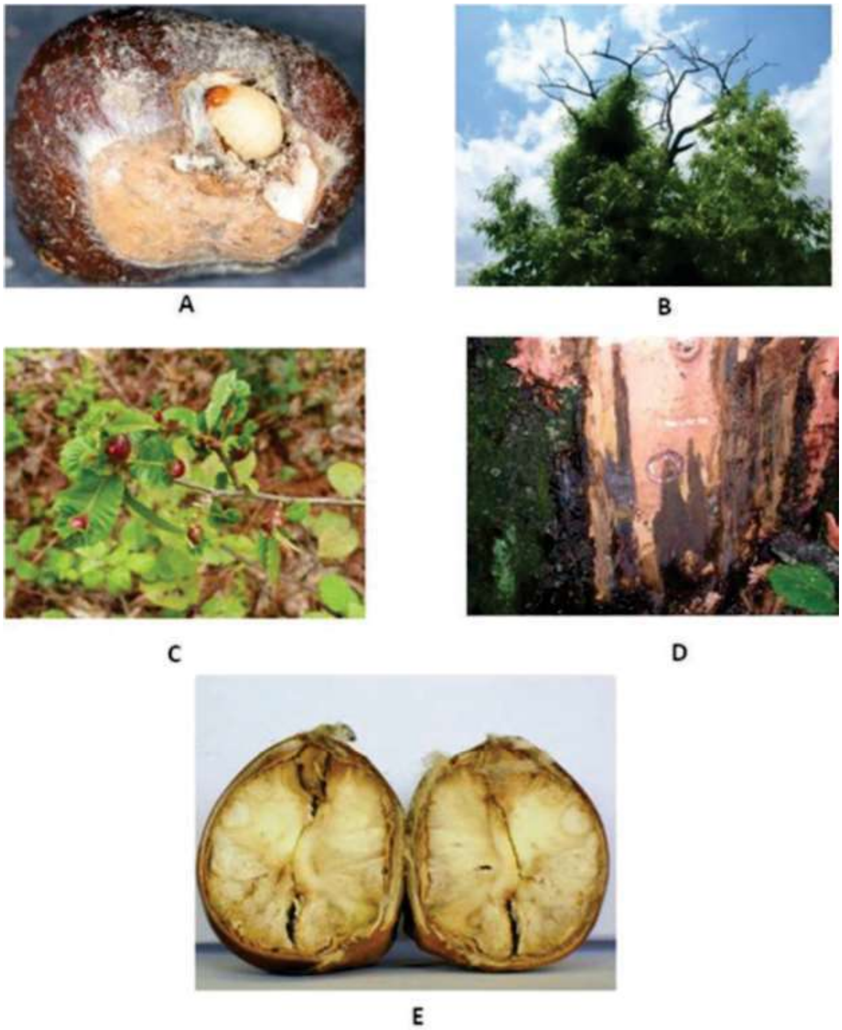


Fig 4. (A) *Curculio elephas* larva feeding on chestnut fruit, (B) death of branches caused by chestnut blight, (C) galls by *Dryocosmus kuriphilus*, (D) necrosis of the cambial layer associated with ink disease, and (E) nut rot caused by *Gnomoniopsis castaneae*.

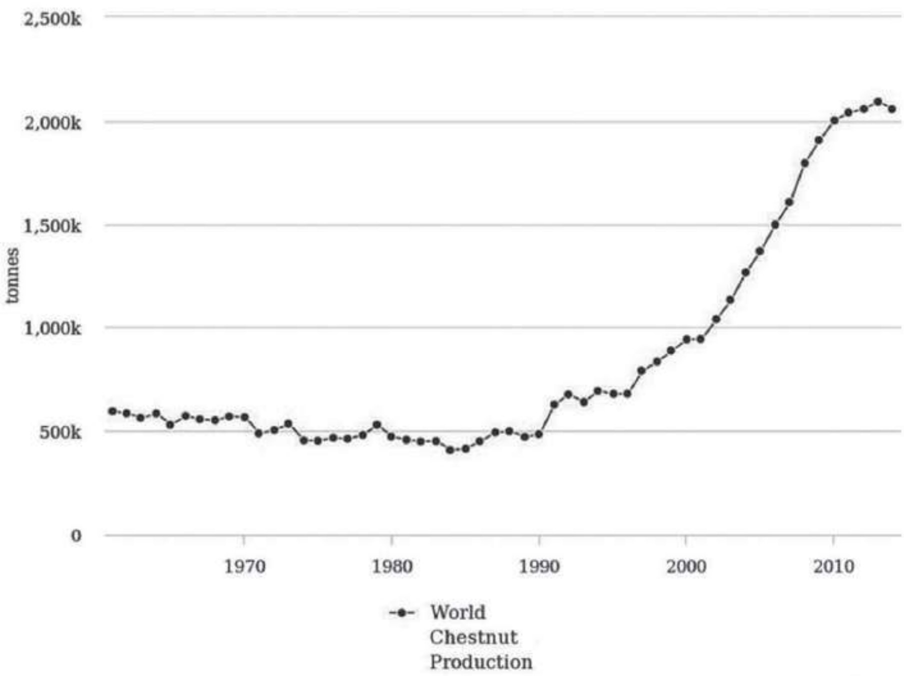


Fig 5. World chestnut production trend from 1961 to 2016 (Food and Agriculture Organization of the United Nations, 2018) (Data source: FAOSTAT).

Constraints associated with Chestnut production

The production of chestnut is impacted by many factors long-standing issues like old and aged plants, senile orchards, small sized farms, poor cultural practices, higher labor cost in harvesting of nuts. One of the major limiting factors is the high slope area in hilly regions are not suitable for effective chestnut cultivation. In chestnut propagation, the major challenges are to get success from micro propagation and nurse grafting. Leaving organic residues in orchards can reduce soil fertility and facilitate the spread of some fungi (e.g., *Gnomoniopsis* spp.). The large trees of chestnut used to respond very poor to fertilizer application. Chestnut is nearly completely self-sterile, although some degree of self-compatibility appears to exist. Poor pollination and improper pollen dispersal mechanism are the other challenges in the cultivation as it leads to production of poor-quality nuts, low productivity. Bees and other insects are drawn to chestnut pollen, which has a distinct odor, but they do not appear to visit the pistillate flowers, presumably due to a lack of nectar which results as the chestnuts are mostly pollinated by the wind. Chestnut cotyledons remain enclosed in a pellicle which is a membranous covering, originating as an integument of ovule. The bur abscission occurred in two phases. The first phase took place in early and late July and the second phase at the end of August. The second phase of abscission seemed to be due to a failure of fertilization. Lack of disease resistant varieties to chestnut blight and phytophthora root rot is another limitation in the cultivation. New invasive pest and pathogen species, climate change, inadequate scientific knowledge on cultivation and technological advancements impacts chestnut cultivation.

Improvement strategies for Chestnut production

Sod mulch system can be adopted in hilly terrain to control soil erosion and to conserve moisture. The chestnut trees were planted at 8 m x 8 m (dwarf one) and 10 m x 10 m (vigorous one). In the propagation of chestnut, overall growth of sprout was better in case of grafting than budding. Nurse grafting with cultivar Dore de Lyon (used as both rootstock and scion) shows more success rate. During the fertilizer application of chestnut, soil application of urea decreased the number of male inflorescences and increased the number of female flowers. Different silvicultural practices can be applied to stimulate host resilience and to contrast chestnut diseases. Management with grafting, pruning, and wounding could be valuable against *C. parasitica*, but it could reduce the effect of hypo-viruses when choosing biocontrol. Concerning Phytophthora management, silvicultural operations can be a good alternative to give vigor to infected plants, but they need to be coupled with drainage interventions in order to stop the ability of Phytophthora to move and spread. Pruning could be a useful method in combination with biological control; however, this technique seems to be laborious and expensive for large commercial growers. The chestnut–oak and chestnut–ash mixtures were considerably less infested than pure chestnut stands and chestnut–pine mixtures, suggesting that the quantity of non-host trees in mixed stands strengthens the associational resistance to invasive pests. 'Shihou', a Japanese chestnut cultivar, has been reported to be resistant to gall wasp. Chestnut flour has been proposed as a very interesting ingredient for the production of innovative and fortified product formulations. Chestnut drying is a key unit operation for the safety and the quality of chestnut flour. Both traditional and industrial methods are used for drying. In the traditional process, the drying of chestnut is carried out using a traditional dry kiln, which usually is building with a two-floor cabin built with local stone, whereas in the industrial process, they use modern drying and milling systems.

Conclusion

In conclusion, this chapter delves into the multifaceted world of chestnuts, offering a comprehensive exploration of their botanical significance, historical relevance, and contemporary importance. From their ancient cultivation to the modern challenges faced by chestnut growers, the chapter provides a nuanced understanding of the tree's journey through time. The ecological role of chestnuts in diverse ecosystems and their economic significance in various cultures are highlighted, underscoring their global impact. The discussion on chestnut breeding and genetic improvement reflects the ongoing efforts to enhance yield, quality, and resilience, crucial in the face of evolving environmental conditions. Furthermore, the culinary and nutritional aspects of chestnuts are unravelled, showcasing their versatility in gastronomy and their potential as a sustainable food source. The chapter underscores the need for continued research and conservation efforts to safeguard the diversity of chestnut species, acknowledging their vulnerability to diseases and changing climates. In essence, this chapter serves as a valuable resource for scholars, researchers, and enthusiasts alike, fostering a deeper appreciation for the intricate tapestry of chestnuts in our natural and cultural landscapes. As we navigate the intricate web of challenges and opportunities surrounding chestnut cultivation, this exploration sets the stage for future endeavors aimed at ensuring the longevity and prosperity of this remarkable tree.

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